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RESEARCH MEMORANDUM

INVESTIGATION AT TRANSONIC SPEEDS OF THE LATERAL-CONTROL AND HINGE-MOMENT CHARACTERISTICS OF A FLAP-TYPE SPOILER AILERON ON A 60° DELTA WING

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CLASSIFIED DOCUMENT

[redacted]

NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

WASHINGTON
January 11, 1954

[redacted]

[redacted]

Classification [illegible] changed to Unclassified

By [illegible] Nasa Tech Pub Announcement #168
[illegible] AUTHORIZED TO CHANGE)

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RESEARCH MEMORANDUM

INVESTIGATION AT TRANSONIC SPEEDS OF THE LATERAL-CONTROL AND HINGE-MOMENT CHARACTERISTICS OF A FLAP-TYPE SPOILER AILERON ON A 60° DELTA WING

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SUMMARY

An investigation using the reflection-plane technique was made in the Langley high-speed 7- by 10-foot tunnel at transonic speeds of the lateral-control and hinge-moment characteristics of a 0.67 semispan flap-type spoiler aileron on a semispan 60° delta wing of 0.045 maximum thickness ratio. The spoiler aileron had a constant chord of 10.29 percent wing mean aerodynamic chord and was hinged at the 81.9-percent-wing-root-chord station parallel to the wing trailing edge. Tests were made for various spoiler projections with the spoiler-aileron slot open, partially closed, and closed.

The results indicated reasonably linear variations of incremental rolling-moment coefficient and hinge-moment coefficient with spoiler projection except at projections less than -2 percent mean aerodynamic chord and at angles of attack greater than 12°. Results were generally independent of slot geometry.

INTRODUCTION

General interest in thin delta wings has introduced the problem of providing adequate lateral control with linear control hinge-moment characteristics throughout the design speed range. Several exploratory investigations on a delta wing at low speeds (refs. 1 and 2) have indicated that satisfactory lateral control may be obtained with a spoiler. A subsequent investigation at transonic speeds (ref. 3) indicated that the effective angle-of-attack range of a spoiler may be materially increased with a wing slot at the rear of the spoiler. Because the investigations of references 1 and 2 were favorable, a thin 60° delta wing equipped with a flap-type spoiler aileron was designed and tested to determine spoiler effectiveness and hinge moments at transonic speeds.

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The control was used to exploit the inherent spoiler advantages of reduction of control reversal due to wing twist and of minimum structural interference with high-lift and longitudinal control devices. The constant-chord spoiler aileron was hinged at 81.9 percent wing root chord and was arranged so that a slot in the wing was opened as the spoiler was projected. Several variations of slot geometry were investigated.

Reported herein are the lateral-control and hinge-moment characteristics of the spoiler aileron, as mounted on a thin 60° delta wing of aspect ratio 2.31. The wing had beveled leading and trailing edges and the thickness ratio varied from approximately 1.5 percent at the root to 4.5 percent at the 66.7-percent-semispan station. The tests were made on the side-wall reflection plane of the Langley high-speed 7- by 10-foot tunnel at Mach numbers of 0.62 to about 1.08 over an angle-of-attack range of approximately -4° to 36°. Spoiler projections investigated varied from 0 to -6.94 percent wing mean aerodynamic chord.

COEFFICIENTS AND SYMBOLS

$$\Delta C_l = \frac{\text{Incremental rolling moment (uncorrected)}}{qSb}$$

$$\Delta C_n = \frac{\text{Incremental yawing moment (uncorrected)}}{qSb}$$

$$C_h = \frac{\text{Hinge moment about control hinge line}}{2qM_1}$$ (positive moment tends to return spoiler to zero projection)

b	wing span, 0.80 ft
c	local wing chord, ft
$\bar{c}$	wing mean aerodynamic chord, 0.461 ft
S	wing area, 0.277 ft^2
M_1	area moment of spoiler aileron behind hinge line, 0.000253 ft^3
α	angle of attack, deg

δ_s spoiler projection above wing surface measured normal to chord plane, percent mean aerodynamic chord, (negative when trailing edge is up)

ρ free-stream density, slugs/ft^3

q free-stream dynamic pressure, $\frac{1}{2}\rho V^2$, lb/ft^2

V free-stream velocity, ft/sec

M Mach number

R Reynolds number, based on $\bar{c}$

M_a average local Mach number

y spanwise distance, ft

MODEL AND APPARATUS

The semispan wing used in the investigation (fig. 1), was of triangular plan form with a leading-edge sweep of 60°, an aspect ratio of 2.31, and a taper ratio of 0. The wing was essentially a 1/8-inch-thick flat plate with beveled leading and trailing edges. The resulting thickness ratio varied from about 1.5 percent at the root-chord station to 4.5 percent at the 66.7-percent-semispan station, with a constant 4.5-percent-thickness ratio from the 66.7-percent-semispan station to the tip. A brass half-fuselage, the ordinates of which are given in reference 4, was mounted on the model with the fuselage center line coincident with the root chord of the wing.

The wing, in the primary configuration, was equipped with a slotted flap-type spoiler aileron with the hinge line located at 81.9 percent wing root chord and parallel to the wing trailing edge. The spoiler aileron had a constant chord of 10.29 percent of the wing mean aerodynamic chord, and extended from the fuselage to the 66.7-percent-wing-semispan station. In order to determine the effect of slot geometry, the original model configuration was modified as shown in figure 1.

The model was mounted with the wing chord plane normal to the surface of the reflection plane with a 1/32-inch clearance gap between the fuselage and the surface of the reflection plane. The wing butt extended through the reflection plane and was attached to a five-component electrical strain-gage balance mounted in a sealed chamber on the outside of

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the tunnel wall. The spoiler-aileron was connected by a torsion rod which extended through the reflection plane to a strain gage mounted on the butt of the model. Aerodynamic forces and moments were measured by means of a calibrated potentiometer connected to the strain gages.

TESTS AND REDUCTION OF DATA

The tests were made in the Langley high-speed 7- by 10-foot wind tunnel, utilizing the high-velocity flow field over a reflection plane mounted on the side wall of the tunnel as described in detail in reference 4. Typical local Mach number contours with the model removed but with the model position superimposed on the charts are shown in figure 2. The charts indicate a maximum spanwise Mach number variation over the wing semispan of 0.04 and a maximum chordwise gradient of about 0.08. The effective test Mach number was obtained from contour charts similar to those of figure 2 by using the relationship

$$M = \frac{2}{S}\int_{0}^{b/2} cM_a \, dy$$

Incremental rolling-moment coefficient ΔC_l, incremental yawing-moment coefficient ΔC_n, and hinge-moment coefficient C_h, were obtained over a Mach number range of about 0.62 to 1.08 for the wing equipped with the original slotted spoiler aileron, and at several intermediate Mach numbers for the modified configurations. Tests were made over an angle-of-attack range of -4° to 36° and over a spoiler projection range of 0 to -6.94 percent mean aerodynamic chord. Reynolds number for the tests (fig. 3) varied with Mach number from approximately 1.4×10^{6} to 1.8×10^{6}.

Torsional deflections of the control, torsion rod, and mounting assembly, when statically loaded to anticipated aerodynamic load limits, were found to be negligible and therefore no corrections for distortion were applied. The data were not corrected for the presence of the reflection plane.

RESULTS AND DISCUSSION

Control Characteristics of a Slotted Flap-Type Spoiler Aileron

Lateral-control characteristics.- The variation of incremental rolling-moment and yawing-moment coefficients with spoiler projection at various angles of attack and Mach numbers are presented in figures 4(a) and 4(b), respectively, for the original open-slot spoiler-aileron configuration. Below sonic velocities, the variation of incremental rolling-moment coefficient ΔC_l with projection above projections of $-0.02\bar{c}$, was generally linear up to an angle of attack of about 12°, with erratic variations of rolling-moment coefficient at low projections between $M = 0.83$ and 0.89 (fig. 4(a)). At angles of attack above 12° at subsonic speeds, and at all angles of attack at $M = 1.08$, the variation of ΔC_l was nonlinear and generally inconsistent with increase in projection. The variation of incremental yawing-moment coefficient ΔC_n with spoiler projection (fig. 4(b)) was small but favorable at angles of attack up to 4°, becoming generally unfavorable with increased projection at high angles of attack.

Hinge-moment characteristics.- At low spoiler projections up to -2 percent mean aerodynamic chord, the variation of hinge-moment coefficient C_h with projection (fig. 4(c)) was very nonlinear, tending to reversal in sense at nearly all Mach numbers and angles of attack. (This reversal in sign of C_h at low projections is a characteristic of spoiler-ailerons of this type and indicates the tendency of the control to open in the direction of wing lift.) Above a projection of -2 percent, however, there was a generally nonlinear increase of C_h with increase of projection at all Mach numbers and angles of attack.

Effects of Modifications

In an attempt to improve the nonlinear trends of the incremental rolling-moment and hinge-moment characteristics of the original slotted spoiler-aileron configuration, particularly at low spoiler projections, tests were made to determine the effects of several modifications to the spoiler slot. Tests were made with the slot partially sealed and fully sealed, both modifications being made in conjunction with a modified (square) slot trailing edge (fig. 1).

Effects of partially sealed slot and square slot trailing edge.- Control characteristics of the spoiler aileron with partially sealed and square slot trailing edge are presented in figure 5. The variation of incremental rolling-moment coefficient with spoiler projection for the spoiler aileron with the partially sealed slot and square slot trailing edge (fig. 5(a)), showed no significant improvement in linearity at low projections over that of the original slotted configuration. Control effectiveness (absolute value of ΔC_l) at constant angle of attack and projection was generally decreased at all Mach numbers. No significant increase in linearity of the variation of C_h with projection at low projections was apparent (fig. 5(c)).

Effects of sealed slot and square slot trailing edge.- Control characteristics of the spoiler aileron with sealed slot and square slot trailing edge are presented in figure 6. Incorporation of a sealed slot and square slot trailing edge resulted in increased linearity in the variation of ΔC_l with projection and little change in control effectiveness at angles of attack up to 12° for Mach numbers of 0.83 and 0.96 (fig. 6(a)). At $M = 0.62$, however, there was a decrease in linearity and control effectiveness up to a projection of -4.9 percent mean aerodynamic chord.

No significant improvements were noted in the hinge-moment characteristics of the sealed slot configuration other than a decrease in absolute value of C_h at constant control projection at high angles of attack (fig. 6(c)).

Combination of slotted spoiler aileron and deflector plate.- On the basis of results of the tests presented in this paper, the slotted flap-type, spoiler aileron had generally unacceptable control effectiveness and hinge-moment characteristics at control projections of less than $-0.02\bar{c}$ and angles of attack greater than 12°. Incorporation of a linked deflector plate on the lower surface of the wing to aid in directing air through the slot, an arrangement found successful in the investigation of reference 5, is suggested as a possible means of improving the lateral-control effectiveness of the spoiler aileron at the higher angles of attack.

CONCLUDING REMARKS

The results of an investigation of a thin 60° delta wing equipped with a slotted flap-type spoiler aileron reveal that the variation of incremental rolling-moment coefficient ΔC_l and hinge-moment coefficient C_h with spoiler projection was generally linear for spoiler projections above -2 percent mean aerodynamic chord and angles of attack up to about 12° with favorable variations of incremental yawing-moment coefficient ΔC_n at angles of attack below 4°. Extreme nonlinearities in the variation of ΔC_l and C_h, generally occurred at spoiler projections less than -2 percent and at angles of attack greater than 12°.

Closing the slot and changing the slot geometry did not significantly improve the nonlinear trends in the variation of ΔC_l and C_h with spoiler projection.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va. September 29, 1953.

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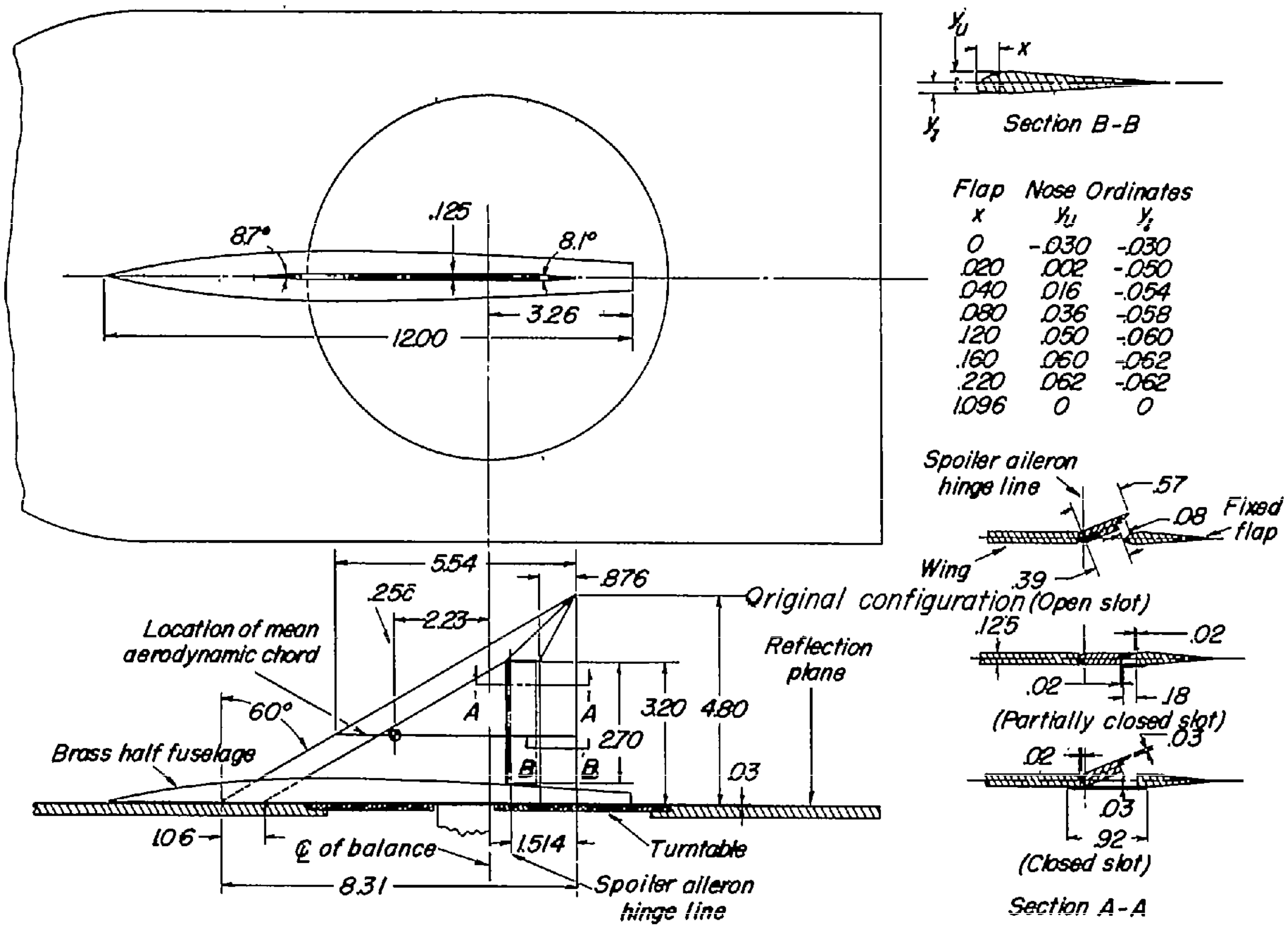


Flap x	Nose Ordinates y_u	y_l
0	-.030	-.030
.020	.002	-.050
.040	.016	-.054
.080	.036	-.058
.120	.050	-.060
.160	.060	-.062
.220	.062	-.062
1.096	0	0

Figure 1.- General arrangement of aspect-ratio-2.31, taper-ratio-0, 60° delta wing equipped with flap-type spoiler ailerons.

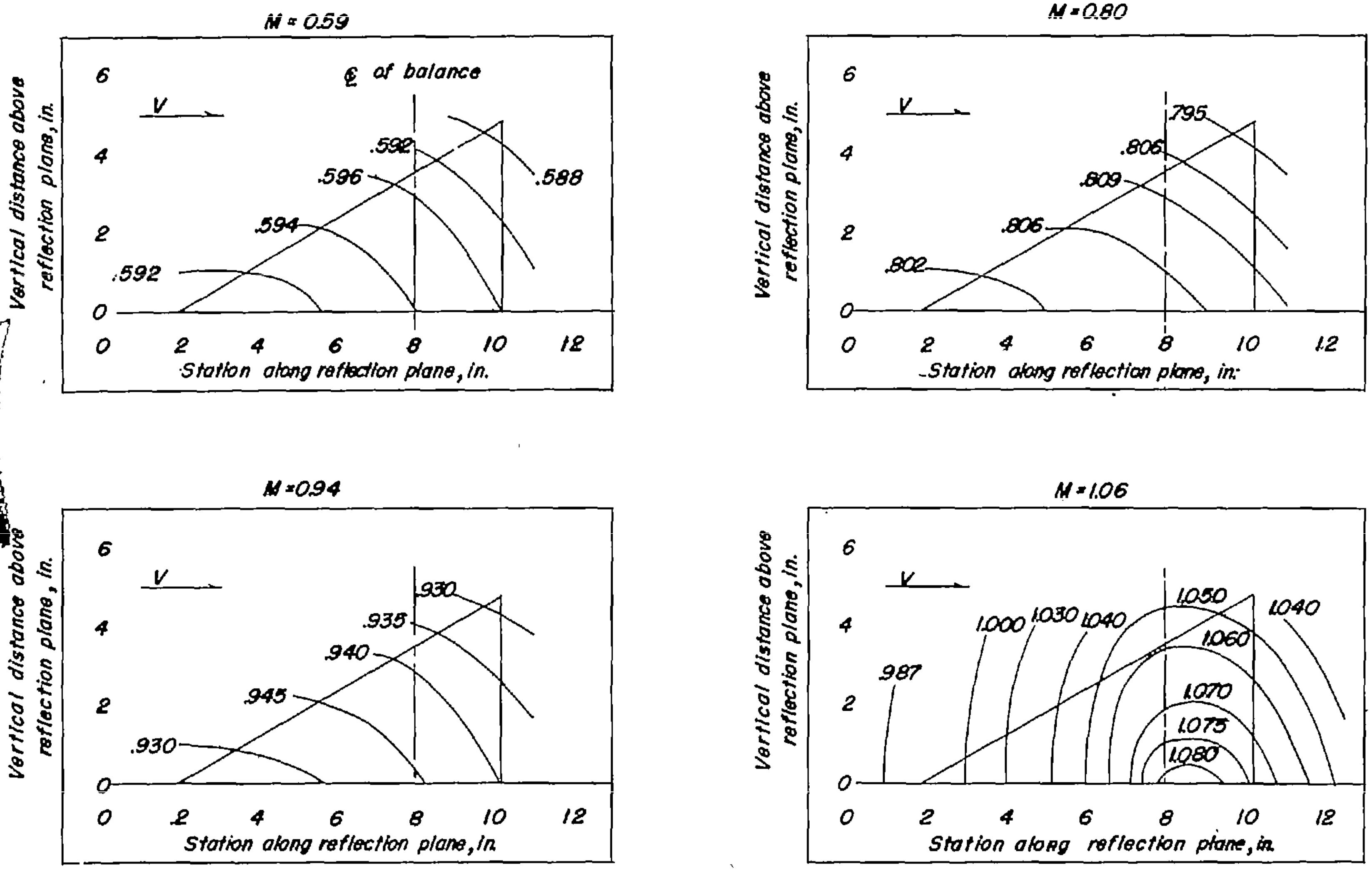


Figure 2.- Typical Mach number variation over surface of sidewall reflection plane.

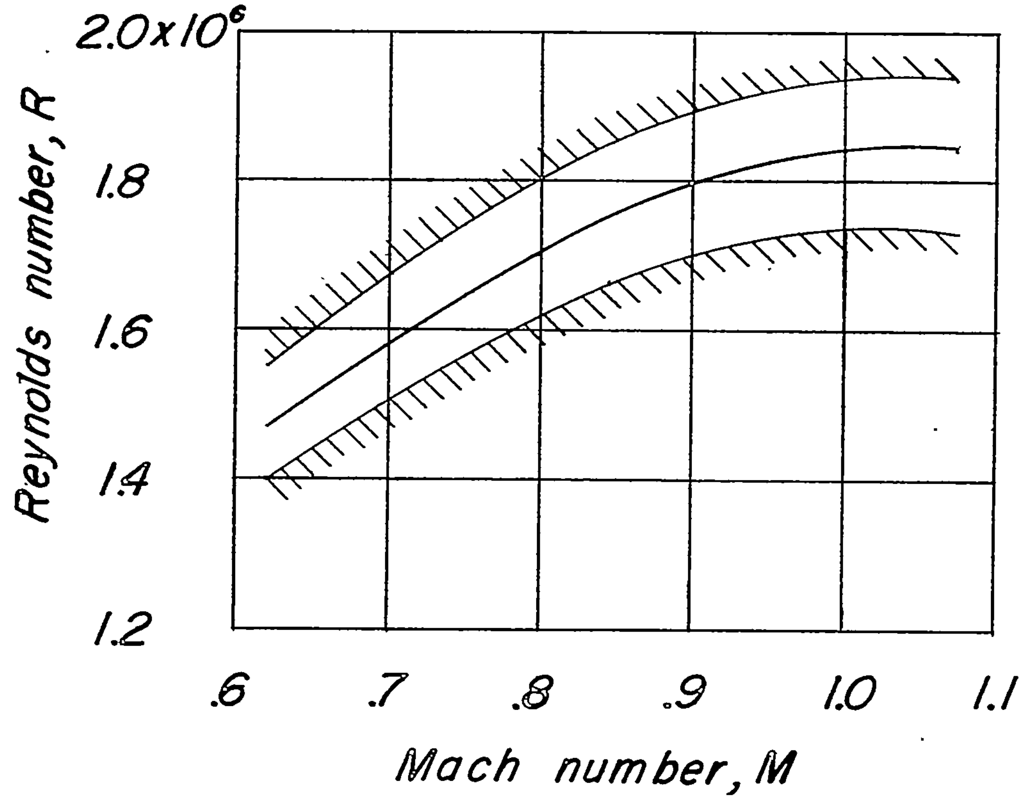
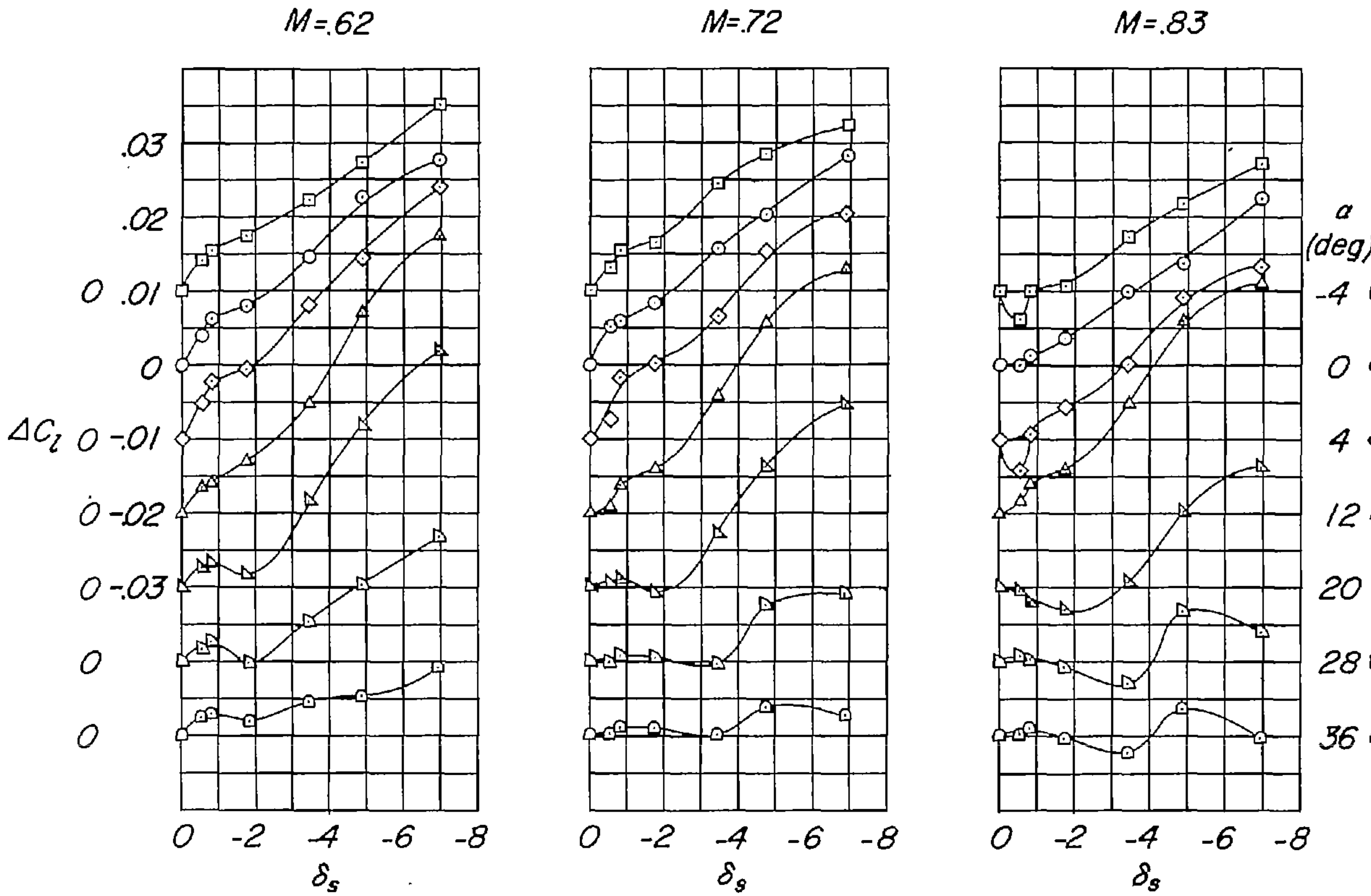
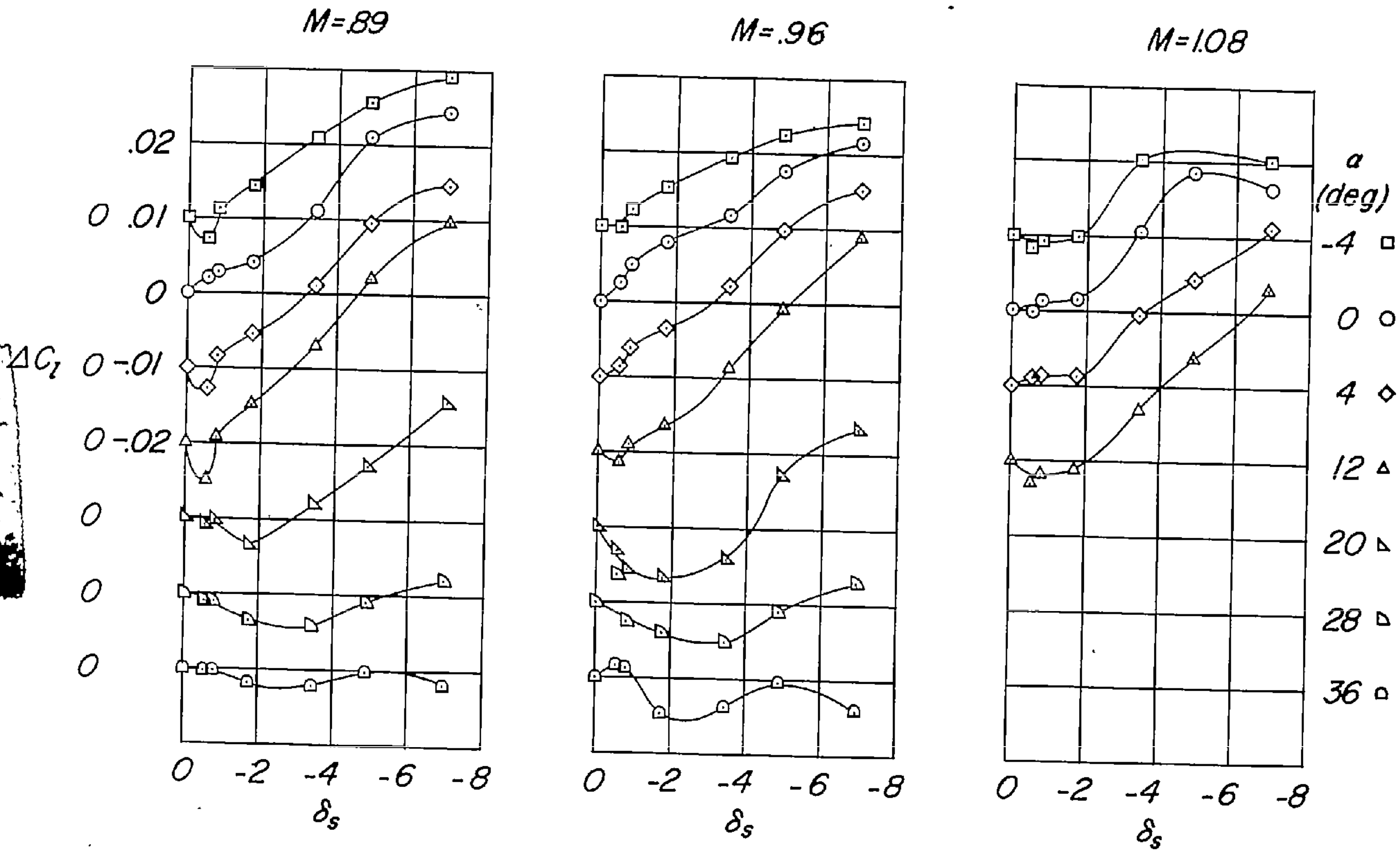


Figure 3.- Variation of test Reynolds number with Mach number for 60° delta-wing model.



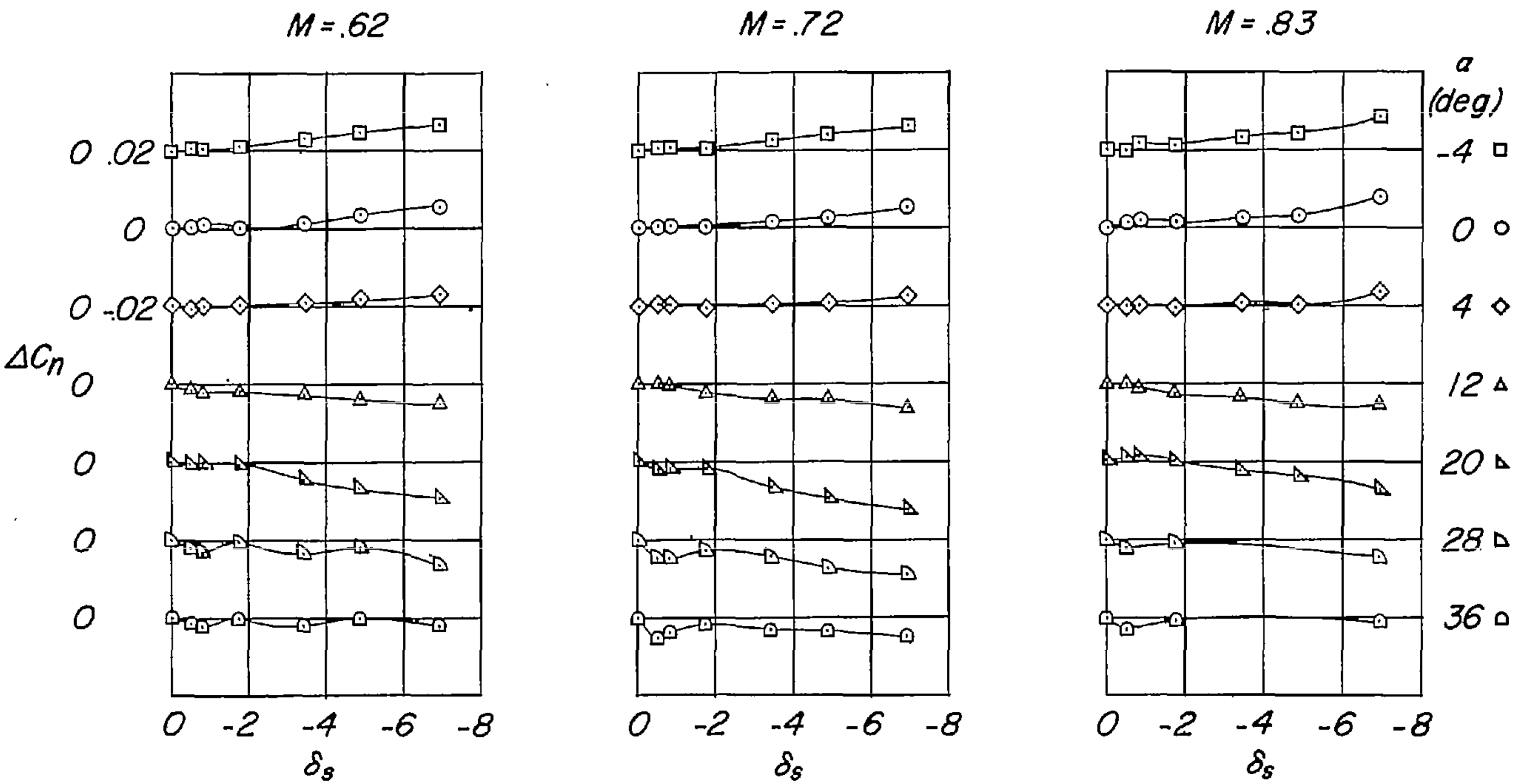
(a) Variation of ΔC_l with spoiler projection.

Figure 4.- Lateral-control and hinge-moment characteristics of a thin 60° delta wing equipped with a spoiler aileron. Slot open.



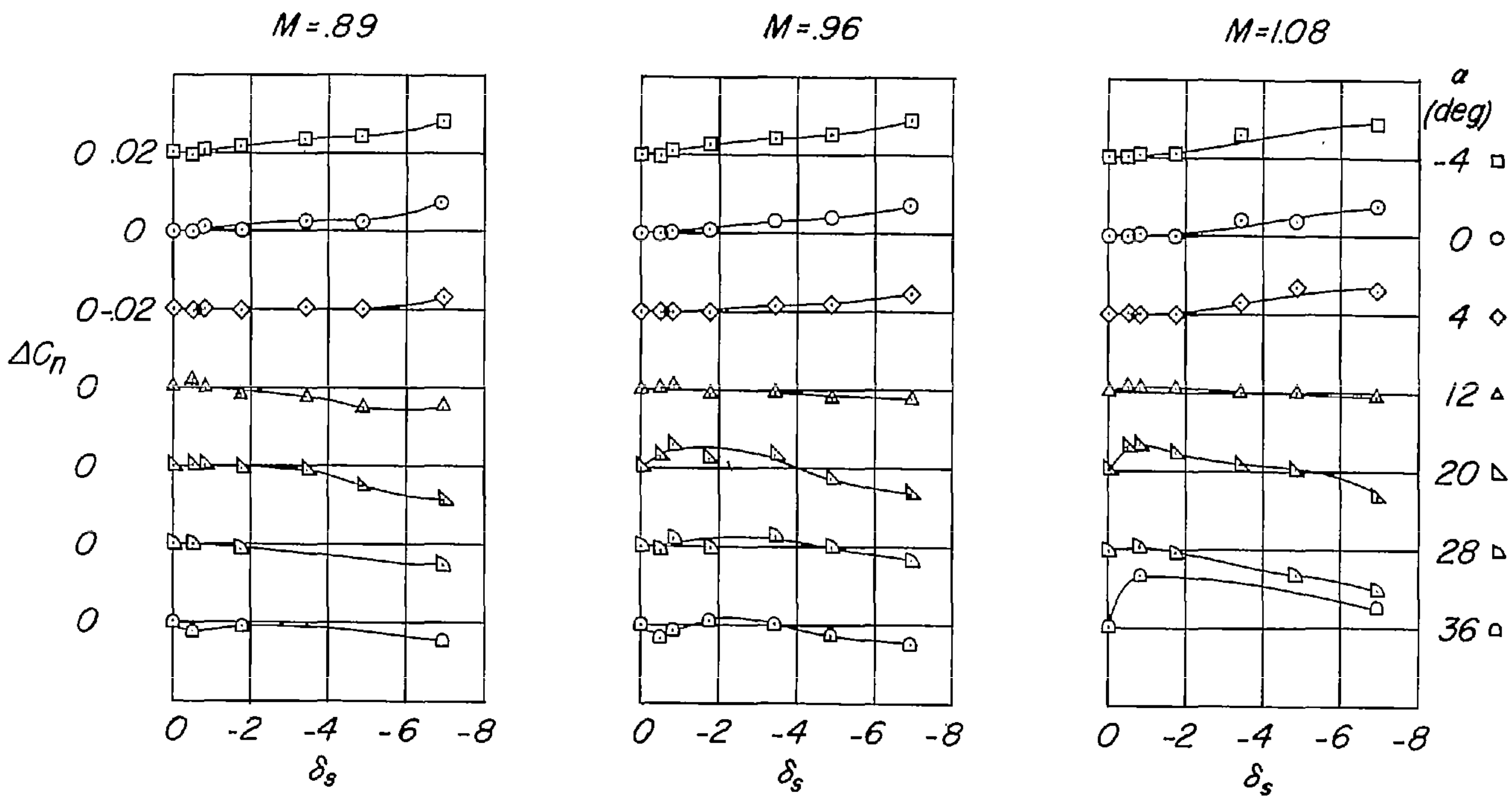
(a) Concluded.

Figure 4.- Continued.



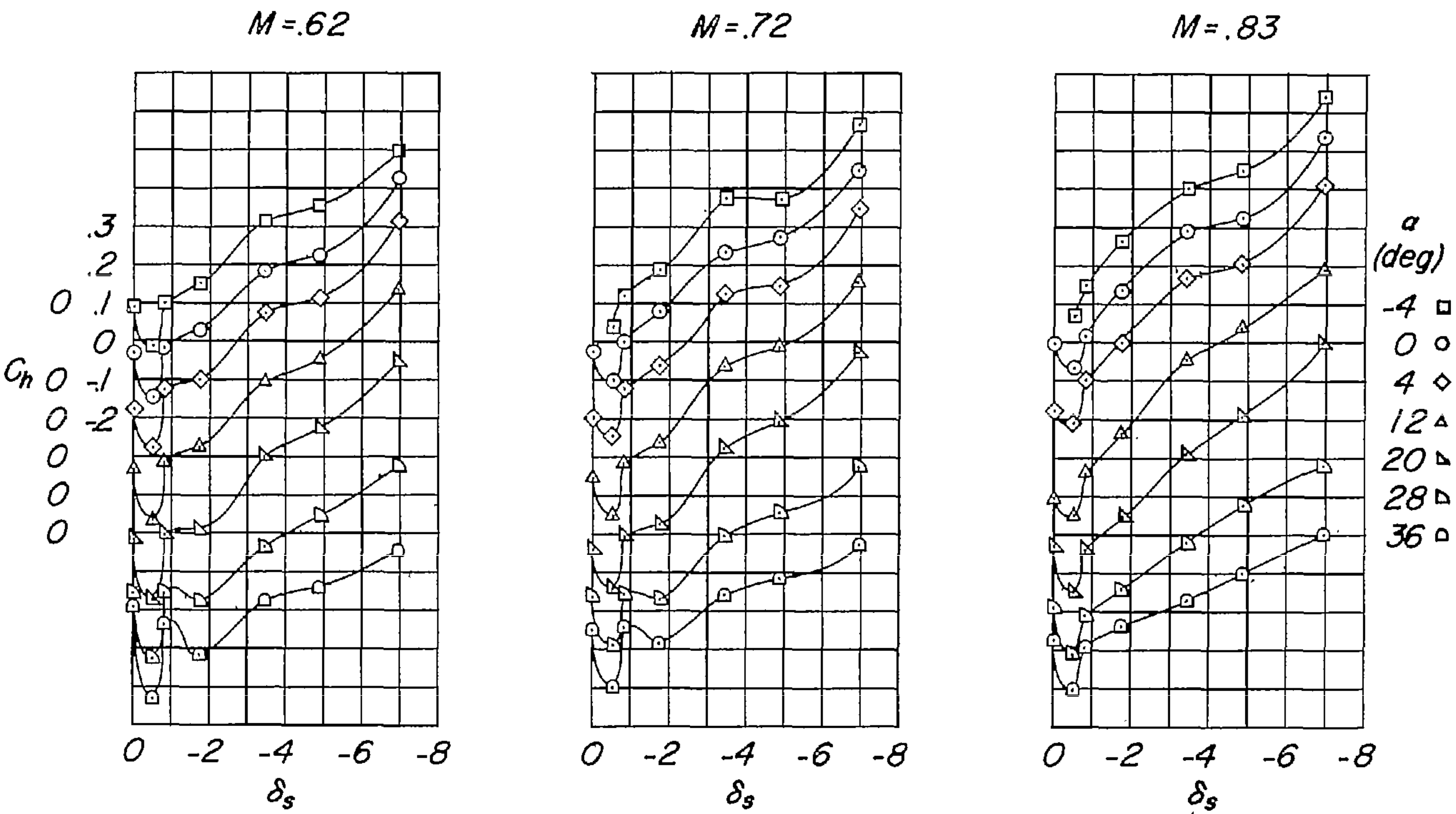
(b) Variation of ΔC_n with spoiler projection.

Figure 4.- Continued.



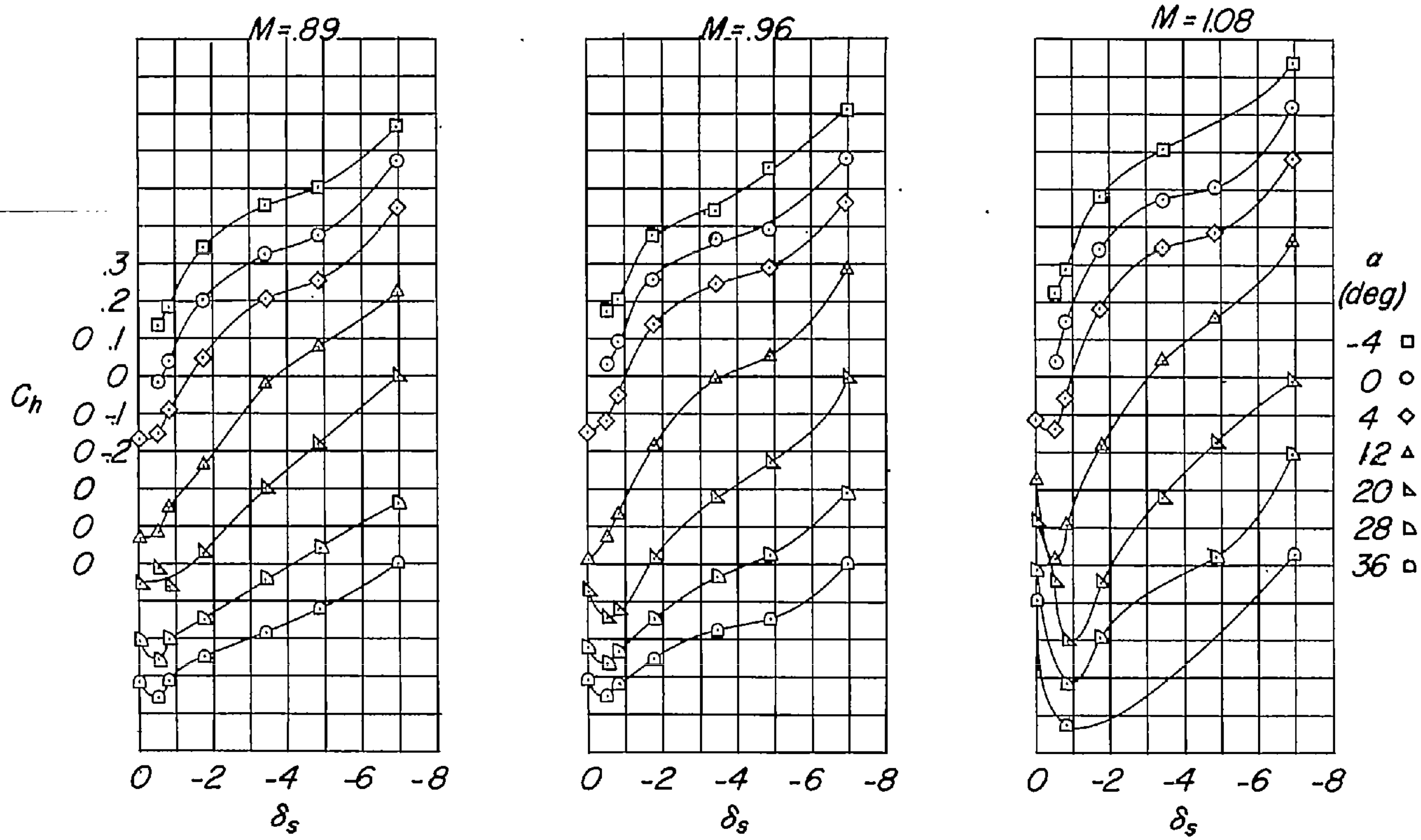
(b) Concluded.

Figure 4.- Continued.



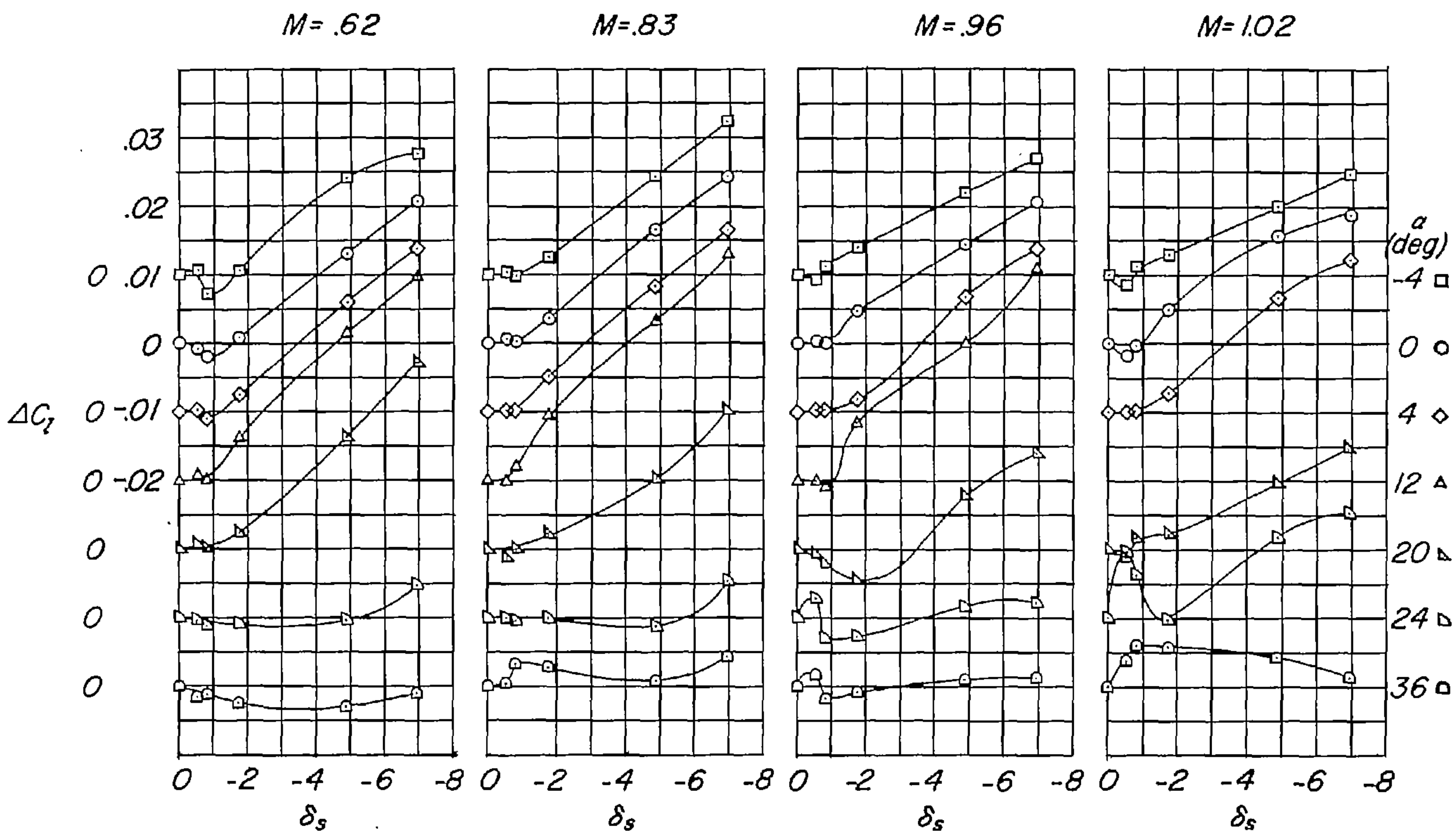
(c) Variation of C_h with spoiler projection.

Figure 4.- Continued.



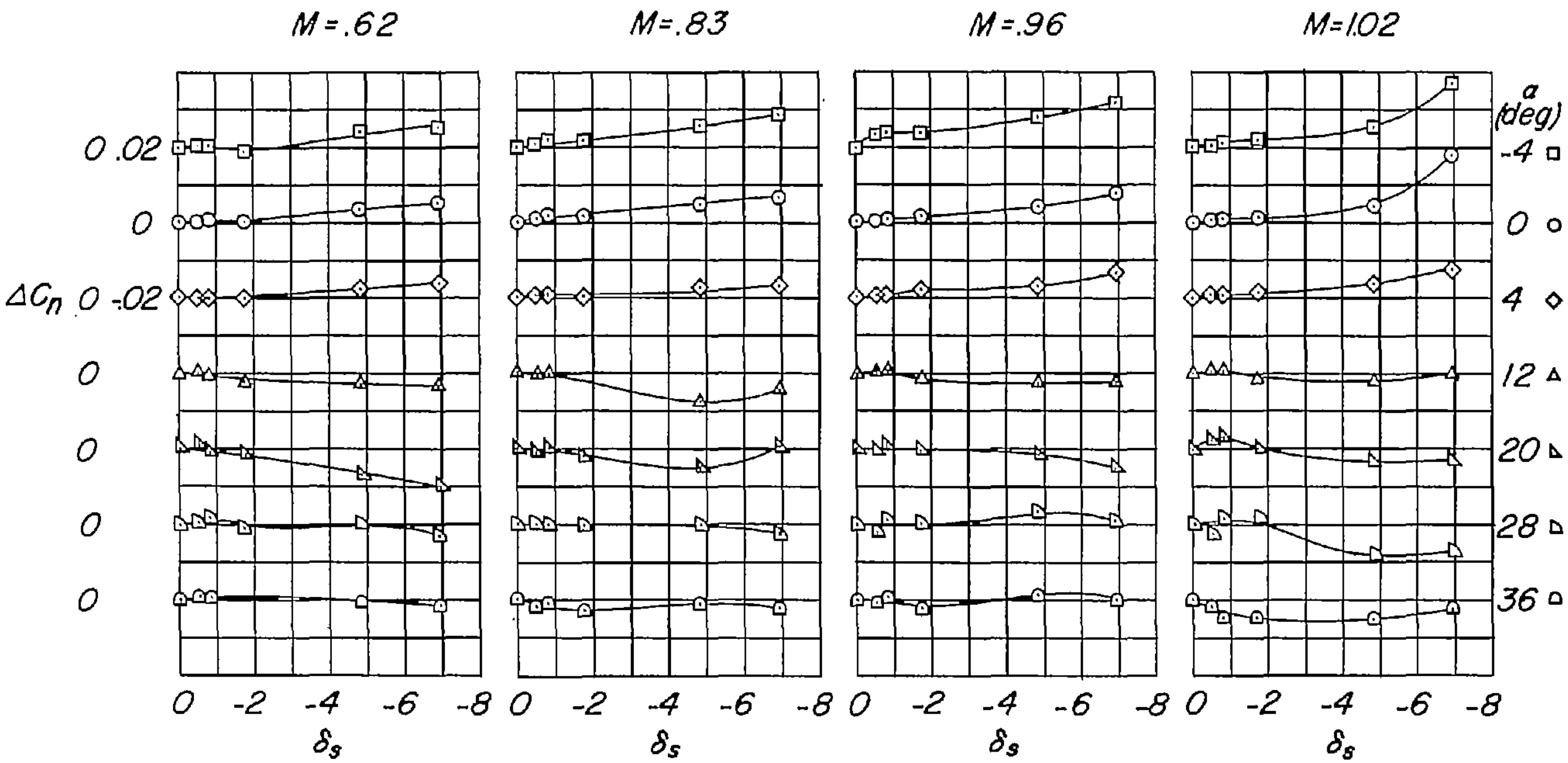
(c) Concluded.

Figure 4.- Concluded.



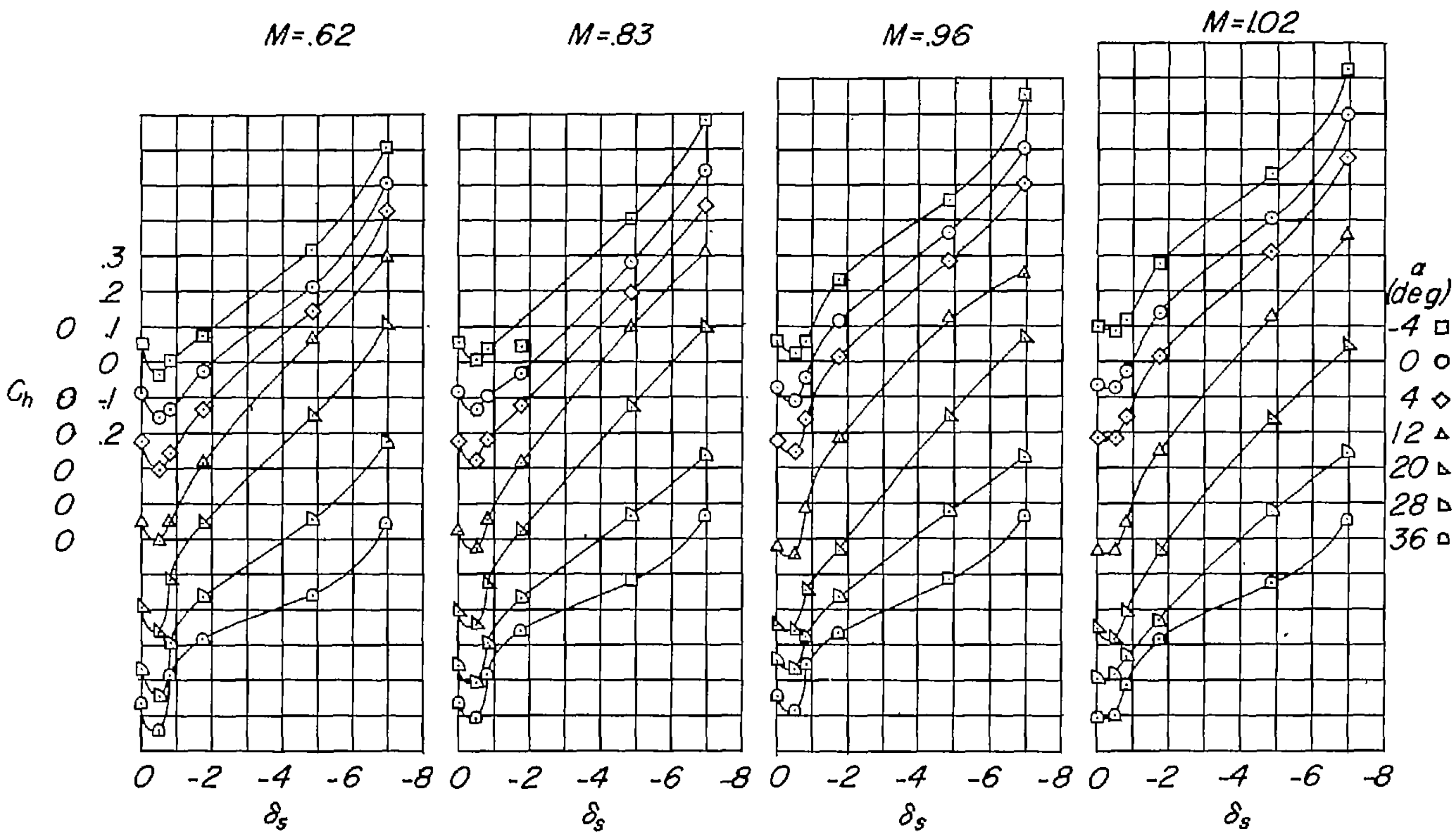
(a) Variation of ΔC_l with spoiler projection.

Figure 5.- Lateral-control and hinge-moment characteristics of a thin 60° delta wing equipped with a spoiler aileron. Slot partially closed.



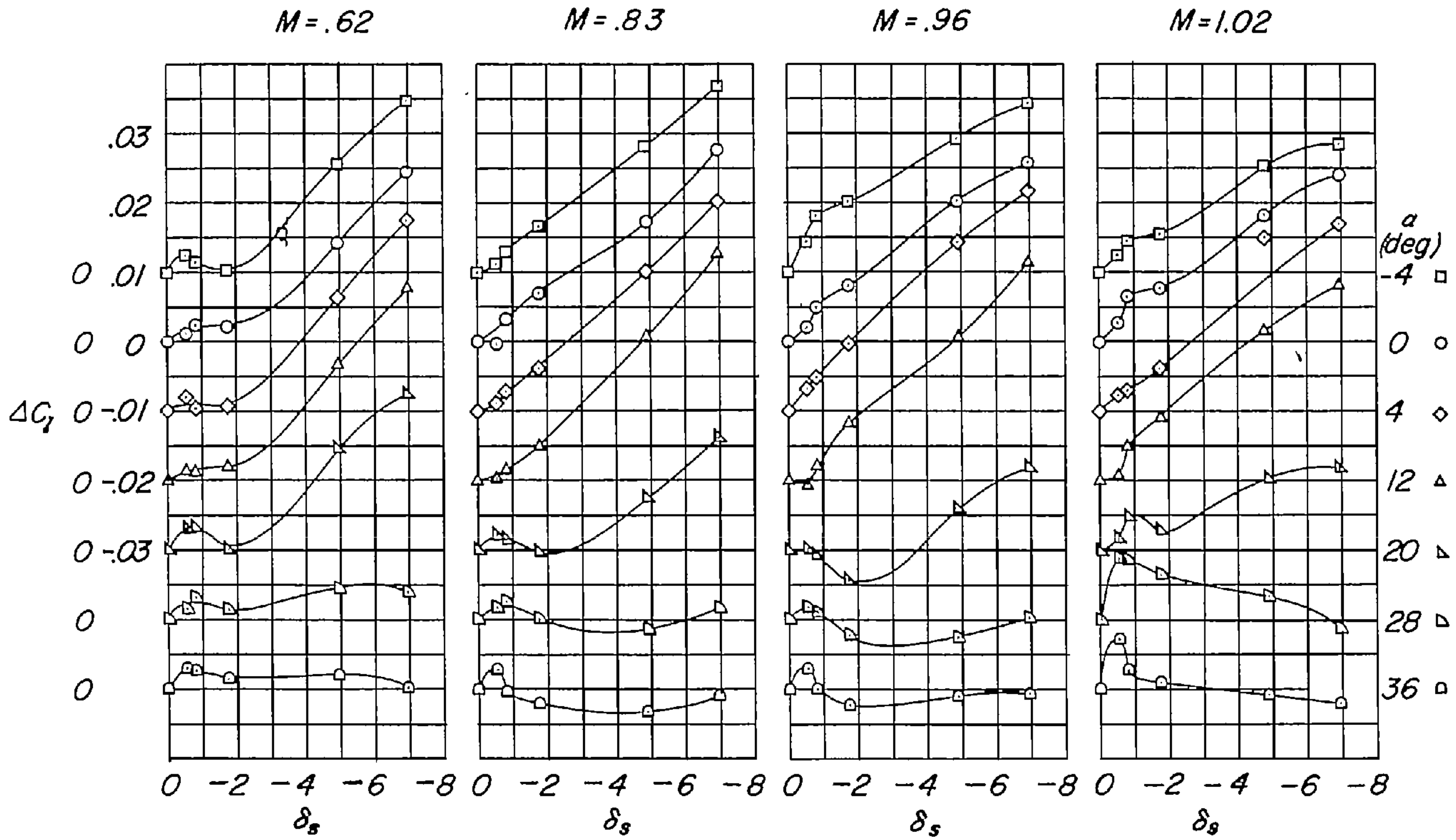
(b) Variation of ΔC_n with spoiler projection.

Figure 5.- Continued.



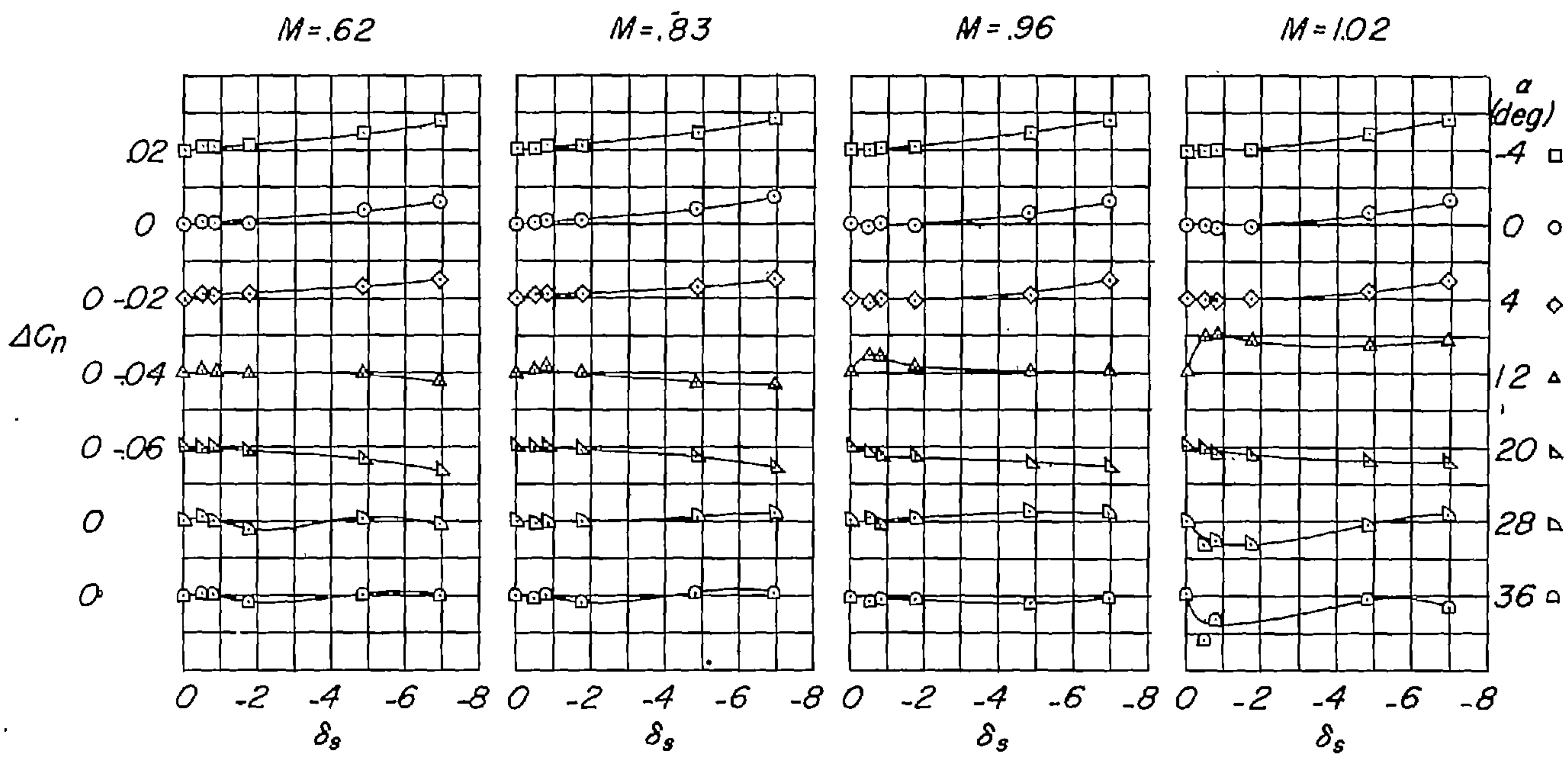
(c) Variation of C_h with spoiler projection.

Figure 5.- Concluded.



(a) Variation of ΔC_l with spoiler projection.

Figure 6.- Lateral-control and hinge-moment characteristics of a thin 60° delta wing equipped with a spoiler aileron. Slot closed.



(b) Variation of ΔC_n with spoiler projection.

Figure 6.- Continued.

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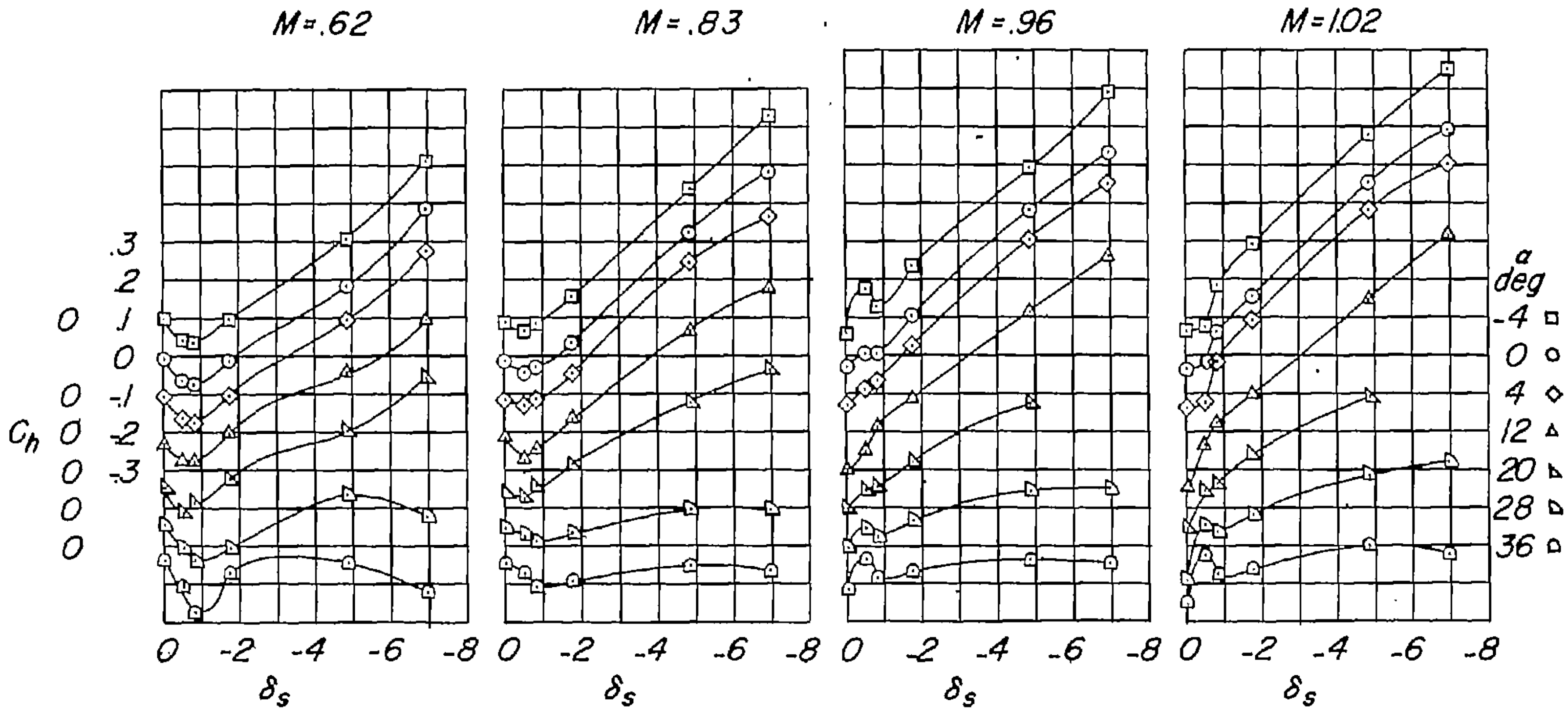

(c) Variation of C_h with spoiler projection.

Figure 6.- Concluded.